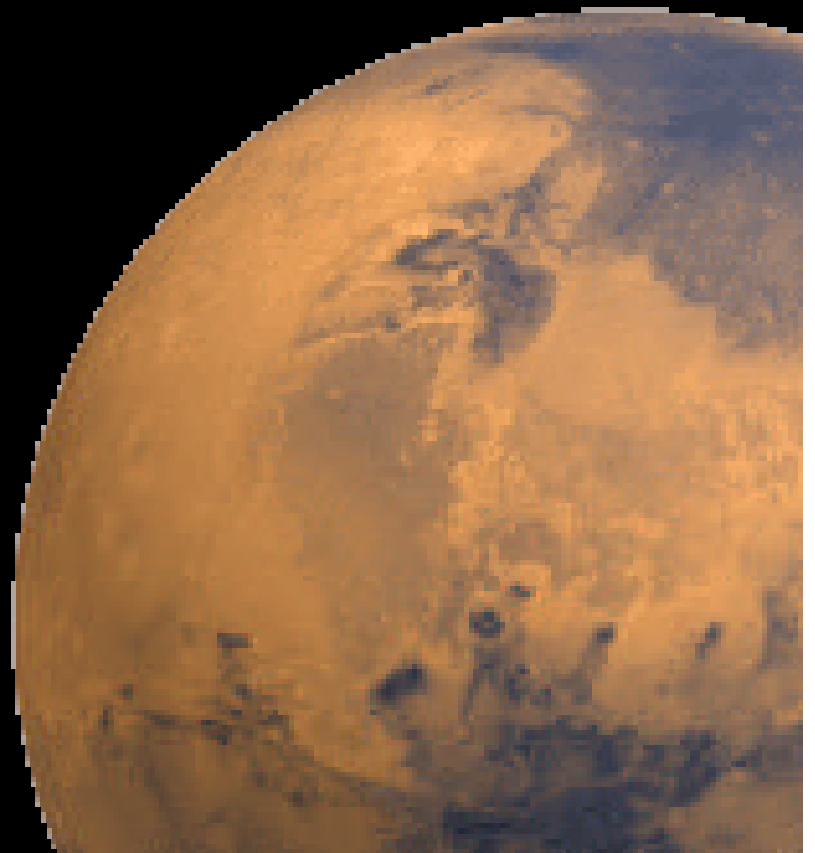


Challenges of Human Space Flight





Contents

- ♦ **Planning for human space mission health and safety**
 - Human
 - System
 - Environment
- ♦ **Confronting biomedical responses to space flight**
 - Physiological response
 - Countermeasures
- ♦ **Advanced technologies for human support**
- ♦ **The International Space Station as a testbed**
- ♦ **Conclusion**



Components of Mission Health & Safety

Human

System

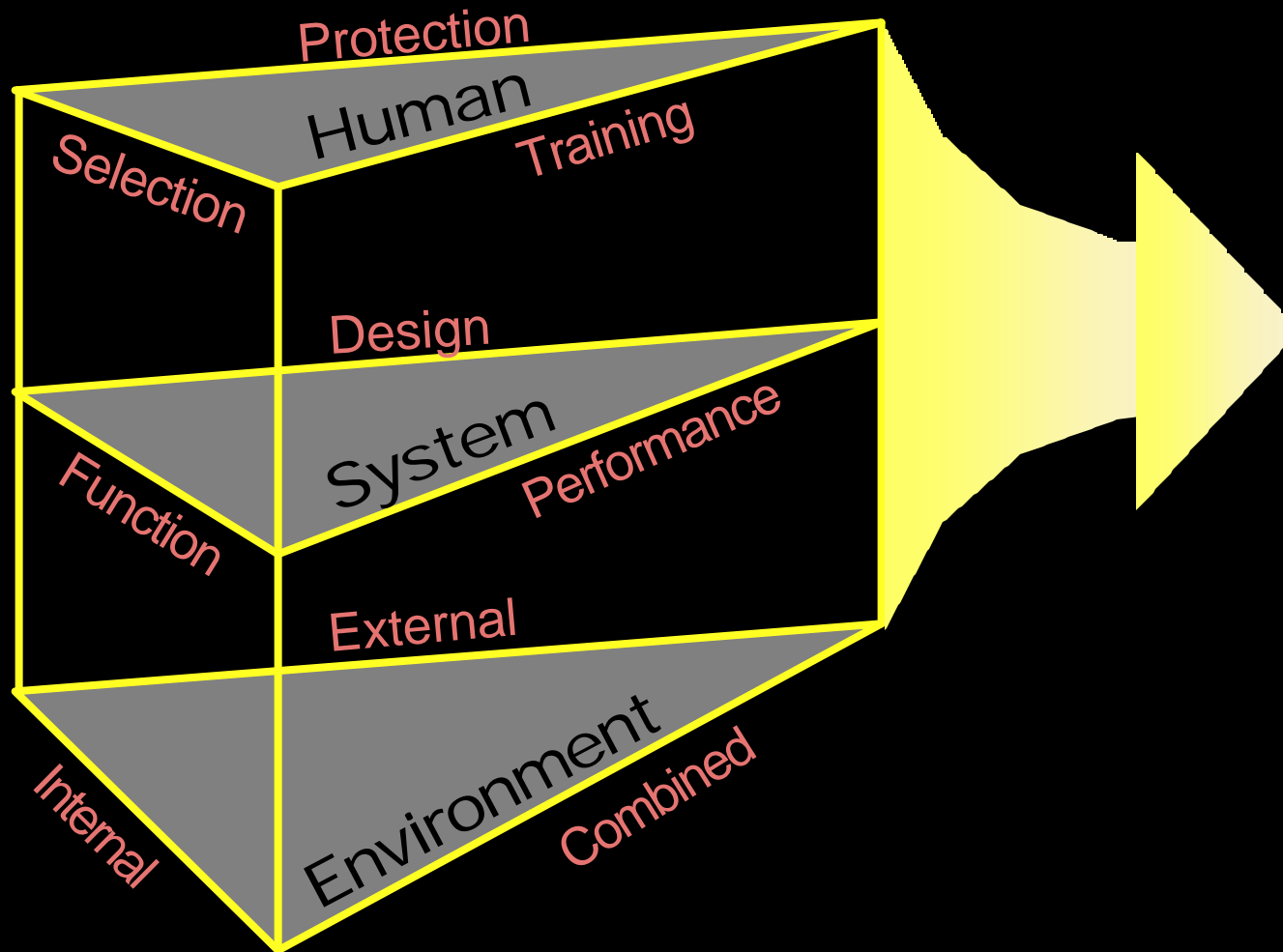
Environment

**Health &
Safety**



System Human
Environment

Human Space Missions



**E
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l
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a
t
i
o
n**



Human
System Environment

Physical Examinations

♦ **Types of examinations**

- Selection
- Retention
- Pre-flight
- Post-flight
- Post-retirement

♦ **Components of examinations**

- Physical exam
- Laboratory analysis
- Imaging
- Special studies

Longitudinal Study of
Astronaut Health



Human
System Environment

Training

- ◆ **Survival**
- ◆ **Mission-specific**
- ◆ **Experiments**
- ◆ **Medical skills**

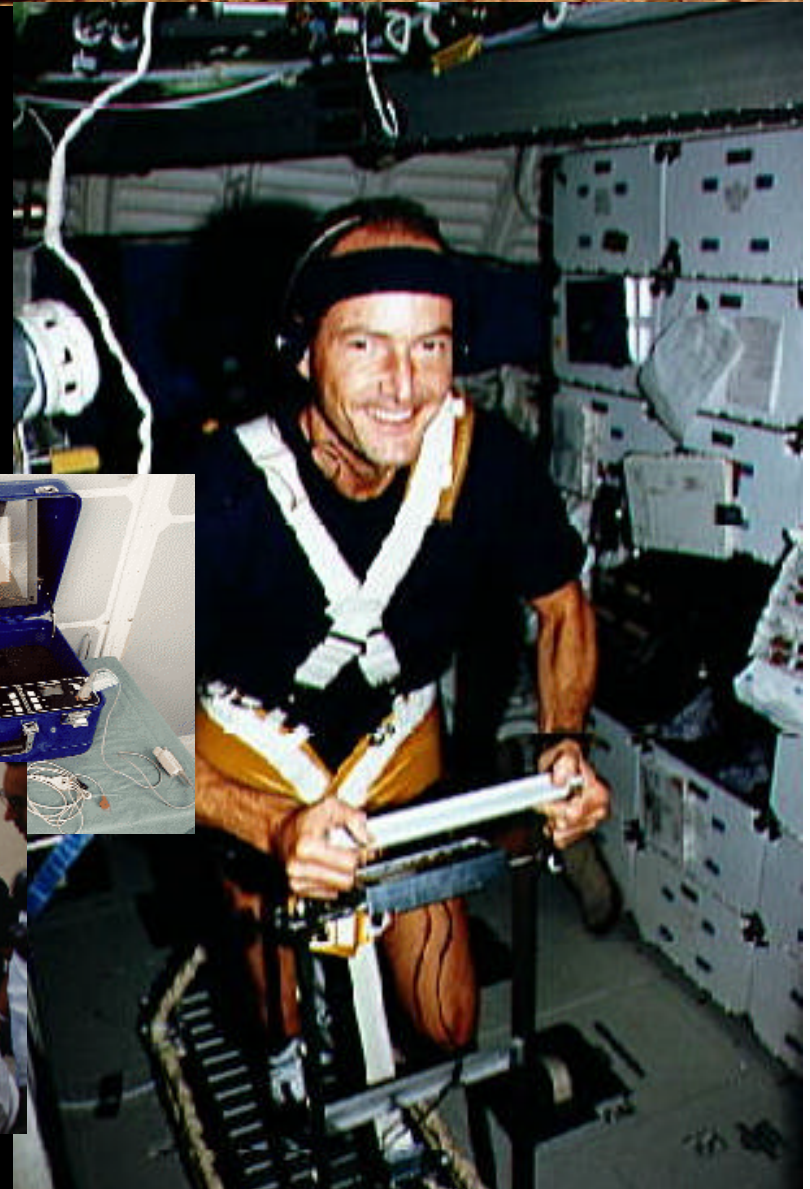




System **Human**
Environment

Protection

- ◆ **Preventive care**
- ◆ **Interventions**
 - Countermeasures
 - Medical care
- ◆ **Life support design choices (system)**





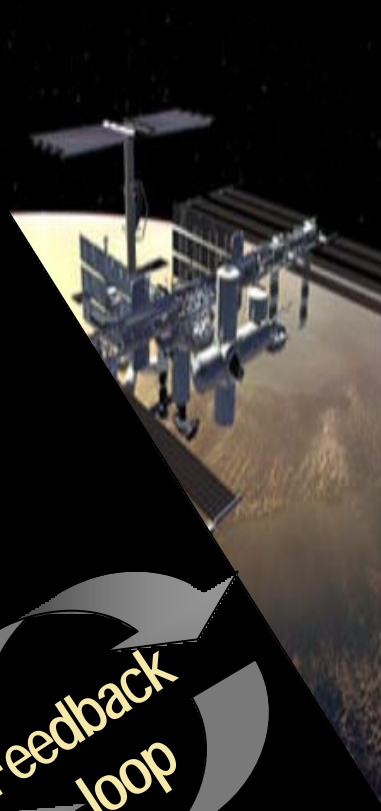
Human
System
Environment

System

Function



Performance



Design





Human
System
Environment

Function

*The System is chosen to fulfill a **function**. This function includes **mission objectives** and **crew protection**.*

- ◆ **Life support**
- ◆ **Environmental control**
- ◆ **Radiation shielding**
- ◆ **Medical capability**



Underlying research

Fluids management
Materials research
Combustion science (fire suppression)
Gravitational biology (biomass production)
Biological interface



Human
System
Environment

Performance

*Performance parameters are chosen to **optimize** system and crew **function**.*

- ◆ System performance parameters/limits
- ◆ Standard operating procedures
 - Vehicle/habitat operations
 - Maintenance procedures
 - Health risk minimization
 - Work/rest cycles





Human
System
Environment

Design

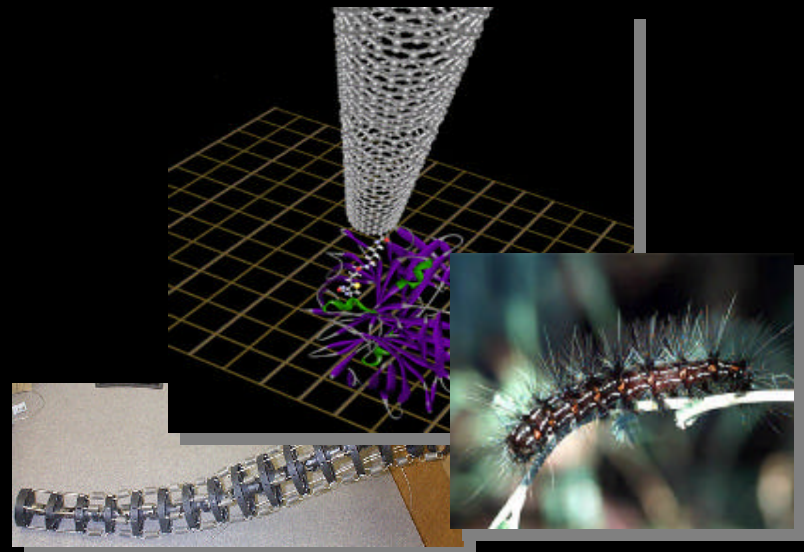
*System design needs to **accommodate constraints** on available power; mass; and crew size, expertise, and availability.*

- ♦ **Miniaturization**
- ♦ **Autonomy**
- ♦ **Redundancy**

Biologically-inspired technologies

- ♦ **Accessibility**
- ♦ **Ease-of-use**
- ♦ **Emergency procedures**

Human factors





System Human
Environment

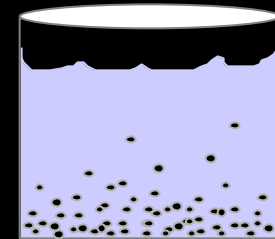
External Microgravity

Convection

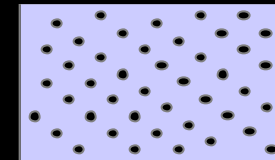
Buoyancy

Sedimentation

Earth



Space



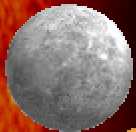
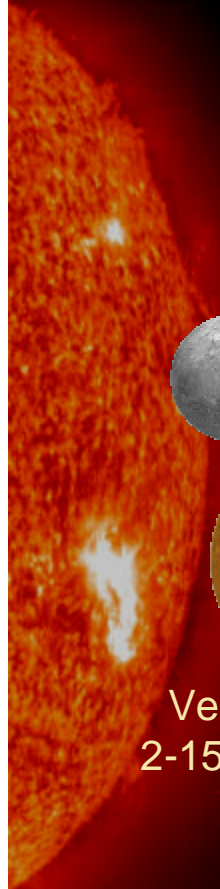


System Human

Environment

External
Time/Distance

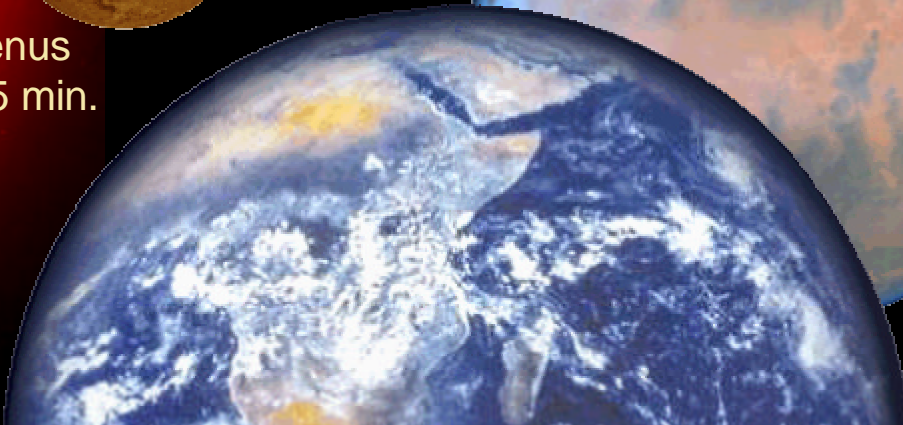
Calling Earth



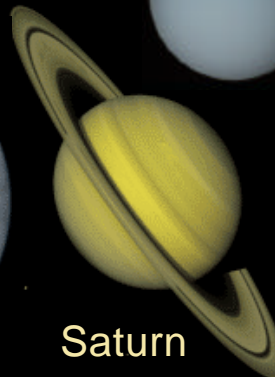
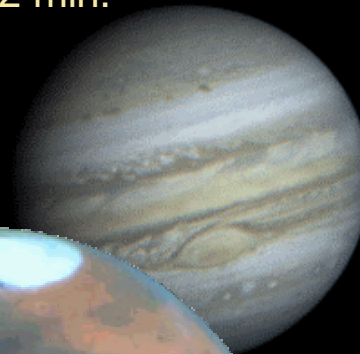
Mercury
5-12 min.



Venus
2-15 min.



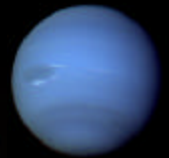
Jupiter
34-52 min.



Saturn
71-88 min.



Uranus
151-168 min.



Neptune
241-259 min.



Pluto
320-337 min.

Mars
4-22 min.

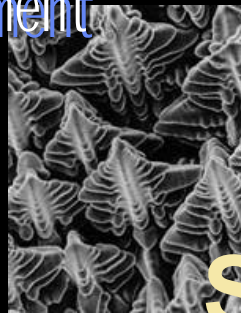




System Human

Environment

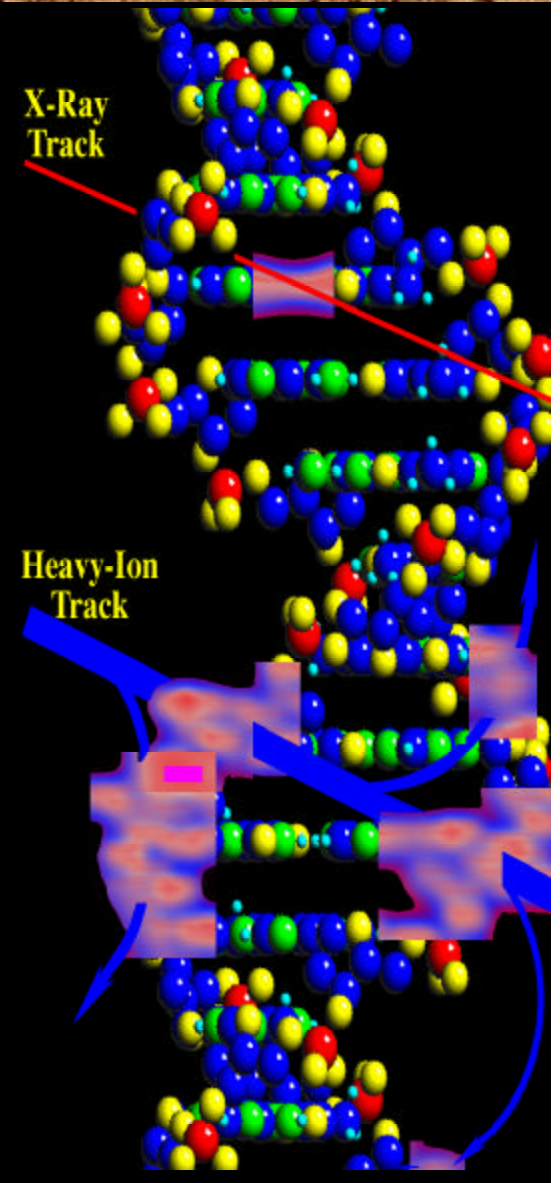
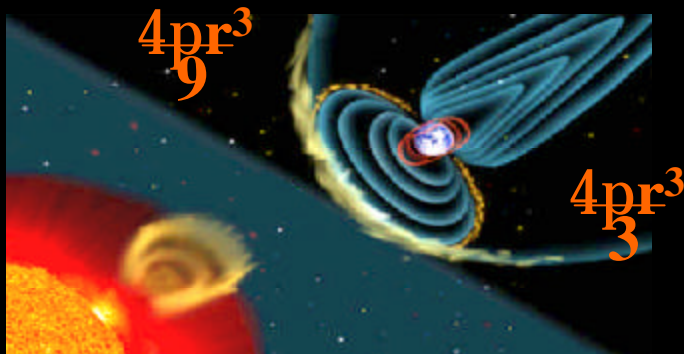
External Radiation



Secondaries

Heavy particles
Protons
Neutrons
Electrons

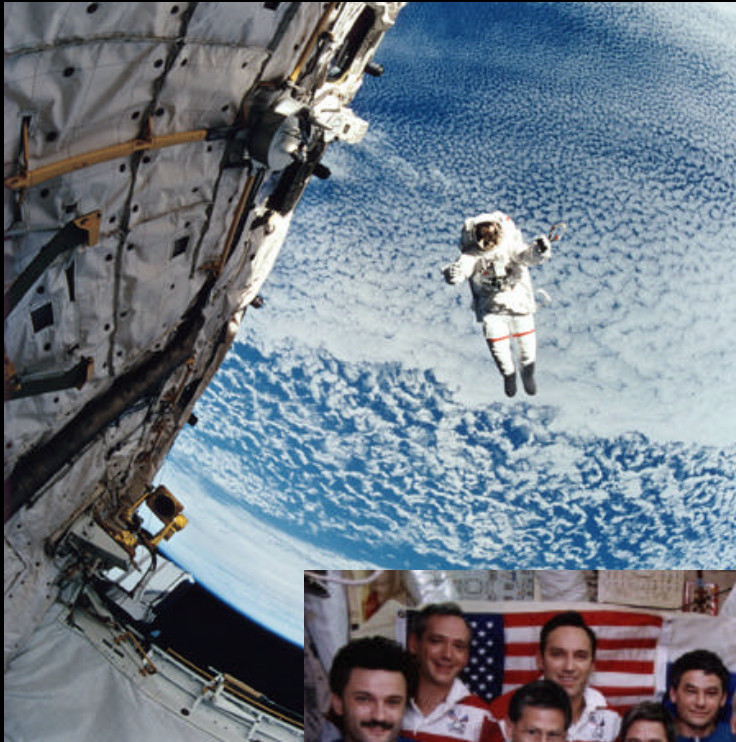
H^-





System Human
Environment

Internal Psychosocial Elements




- ◆ **Isolation**
- ◆ **Confinement**
- ◆ **Multicultural factors**
- ◆ **Societal issues**





Adaptation

-  Adaptive
-  Pathological



Neurosensory & Neuromotor

Cardiovascular/
Pulmonary

Endocrine

Musculoskeletal



parallels with aging...





Muscle Fiber Response

Earth

TSH

+

IGF-1
receptor?

=

Slow and
Fast-twitch
Muscle Fiber
Development

Proposed causal pathway

TSH

+

IGF-1
receptor?

=

Long-chain
Myosin

Slow-twitch
Muscle Fiber
Development

Space



Bone Response

Earth

Bone
Formation
& Density

PTH
&
IGF-I



Osteoprogenitor
Number &
Bone
Mineralization

Space

PTH
&
IGF-I

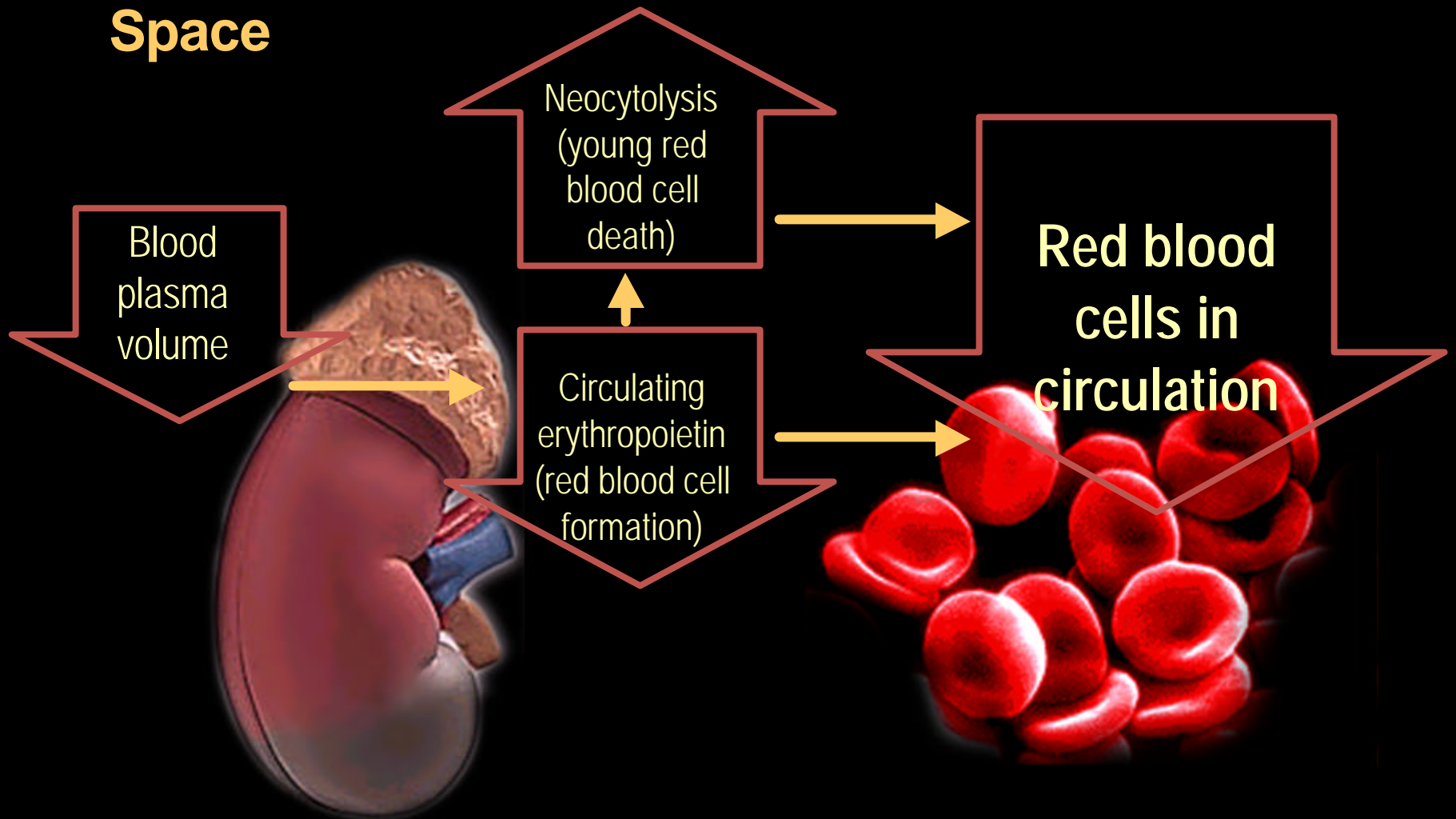


Osteoprogenitor
Number &
Bone
Mineralization



Red Blood Cell Response

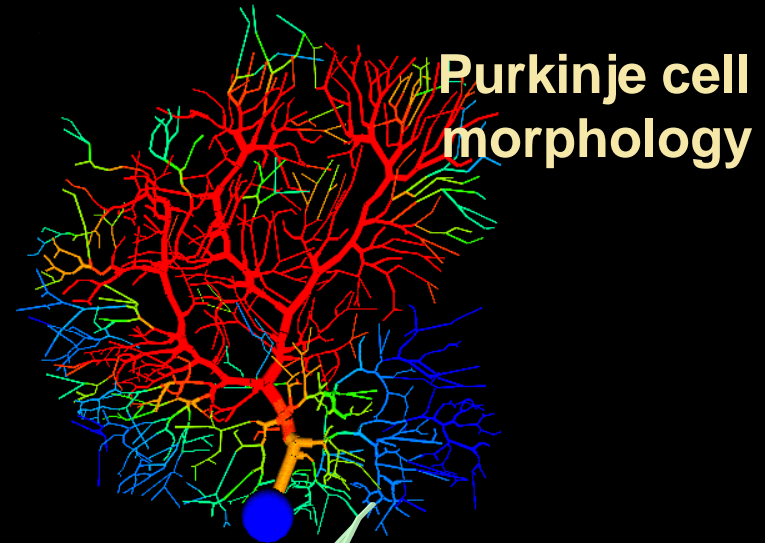
Space





Plasticity

Rapid changes in
function and
structure to **high**
or **low**
acceleration
forces



Purkinje cell
morphology

Type of
Response



Synapses

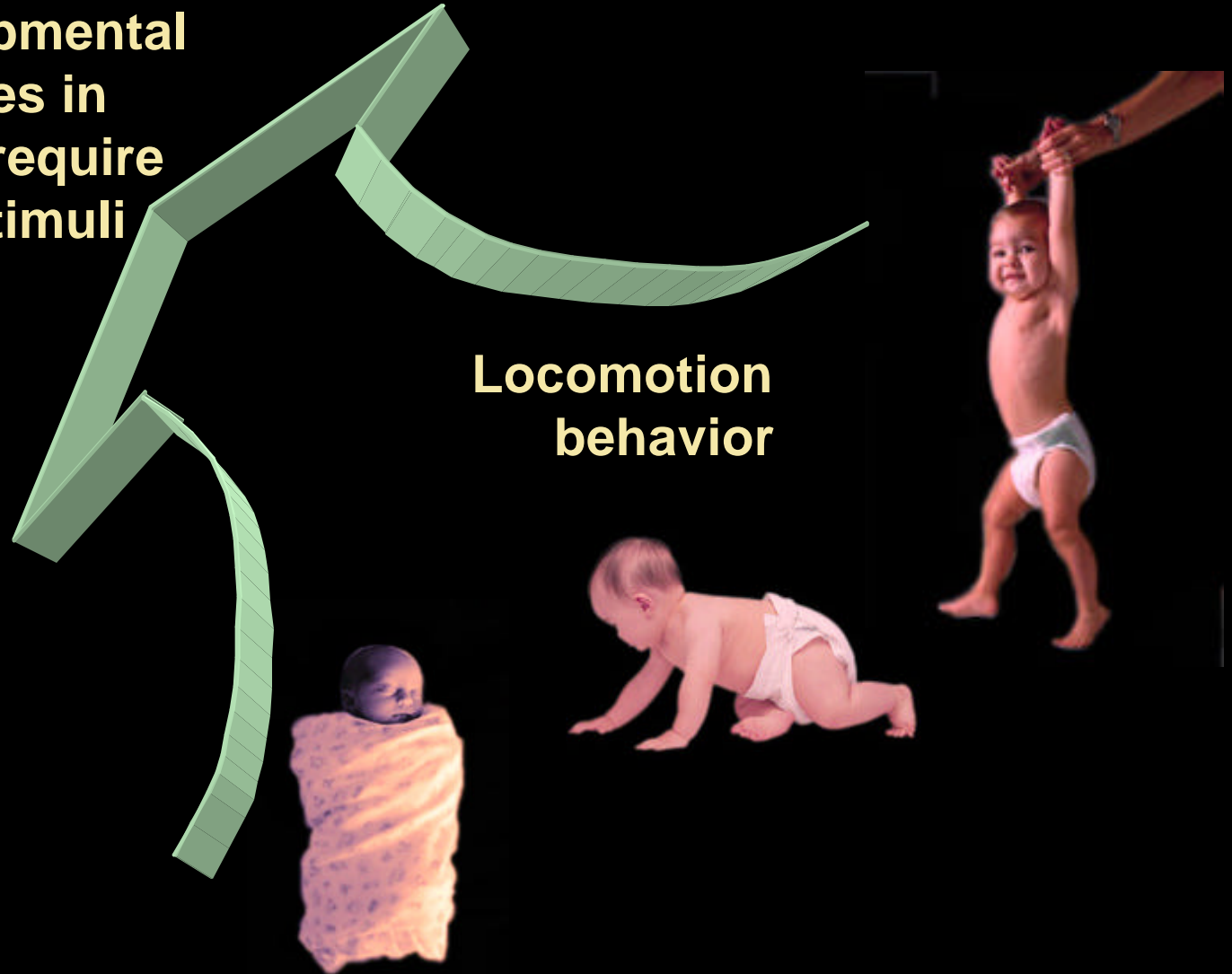
Ataxia
SMS
Ocular



Development

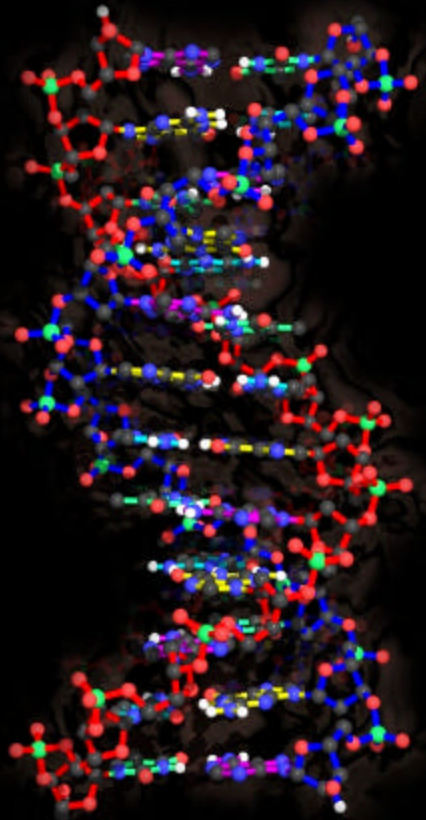
**Key developmental
processes in
mammals require
gravity stimuli**

**Locomotion
behavior**



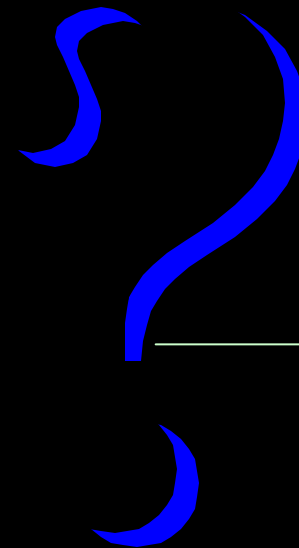


Molecular Observations



Gene
expression ↓↑

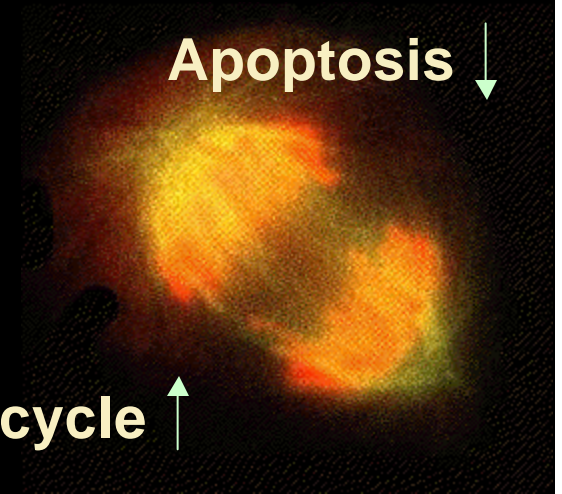
Calmoduline ↓



Ca^{2+} ↓
↓↑

Apoptosis ↓

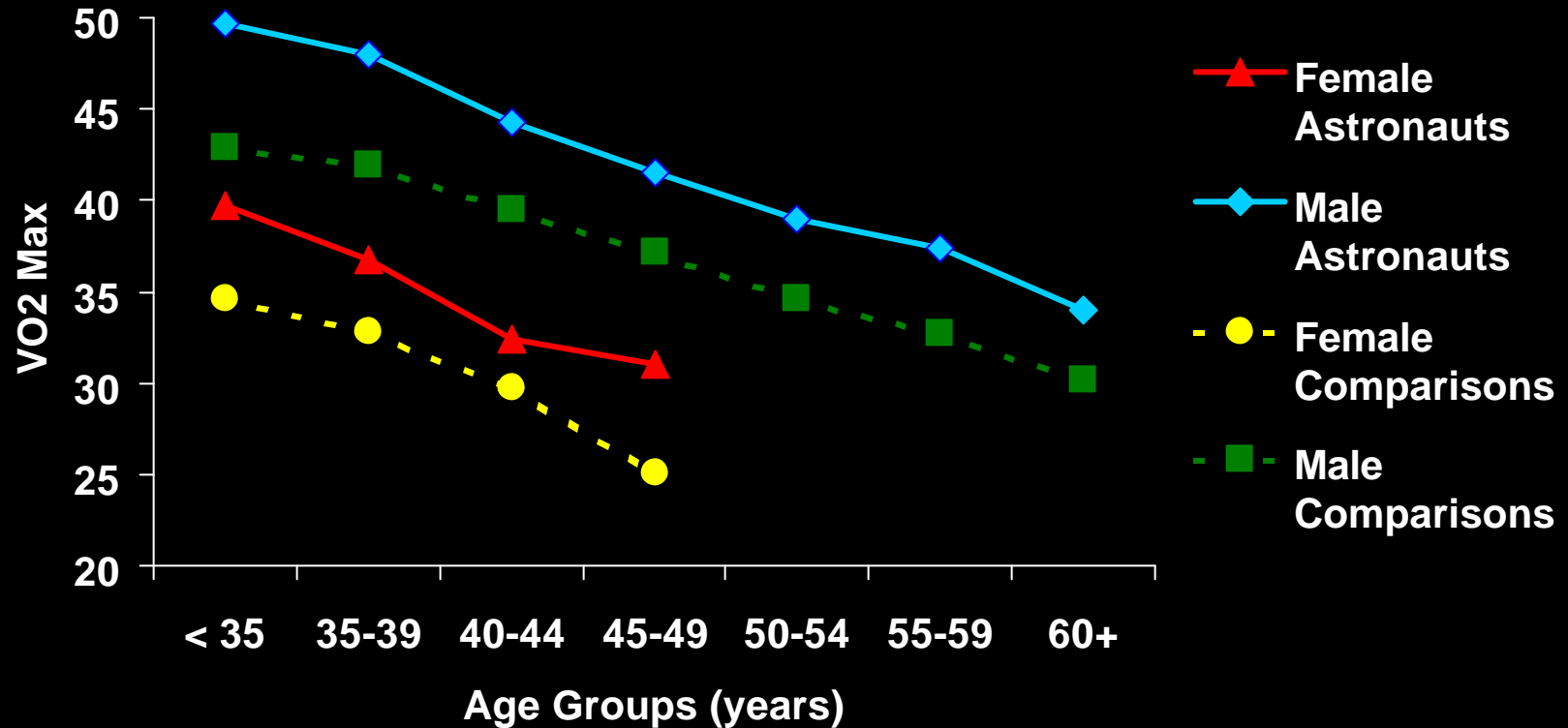
Cell life-cycle ↑





VO₂ Max

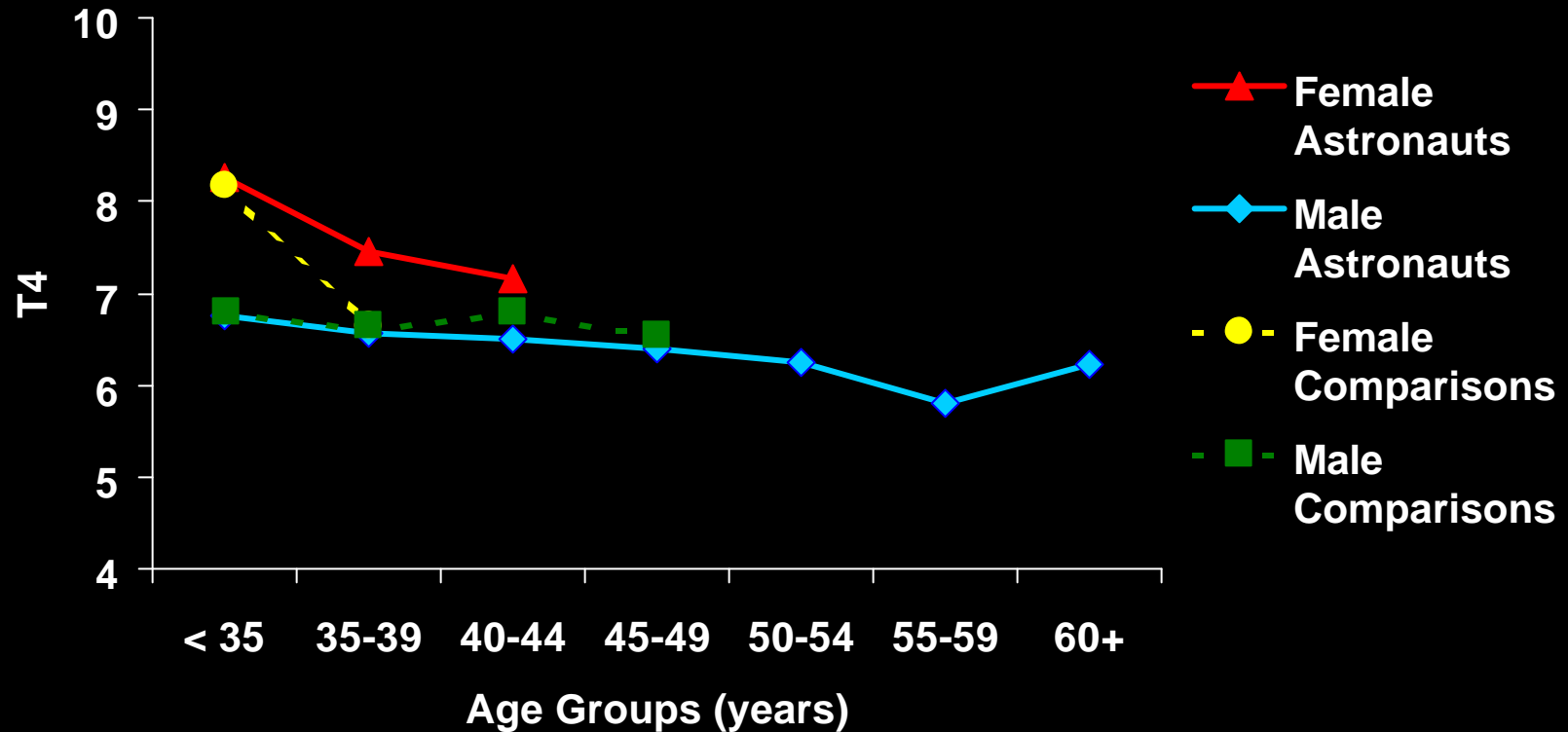
Mean Values by Age (Cross-Sectional Data)





Thyroxine (T4)

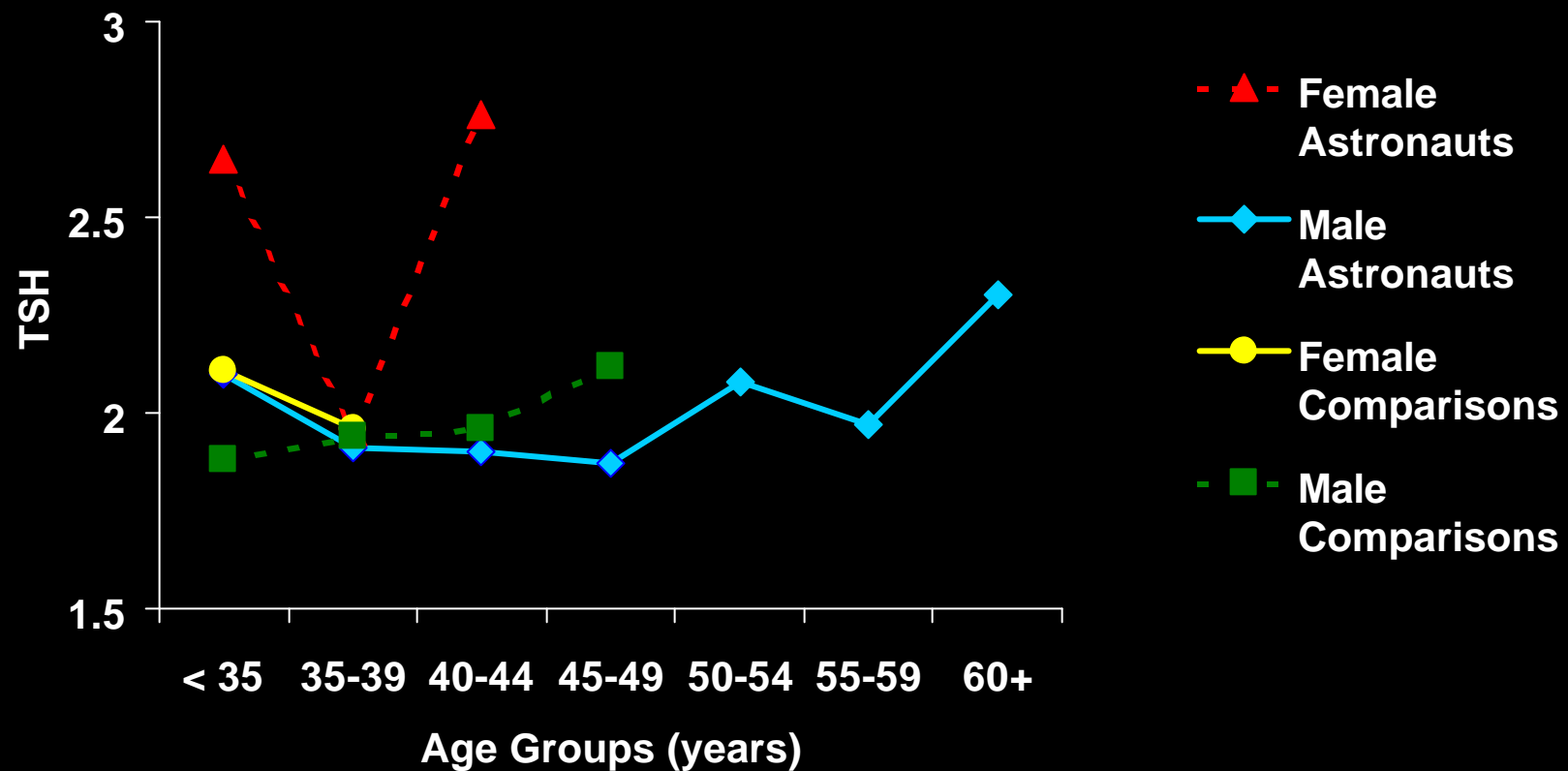
Mean Values by Age (Cross-sectional data, 1991-1998)





Thyroid Stimulating Hormone (TSH)

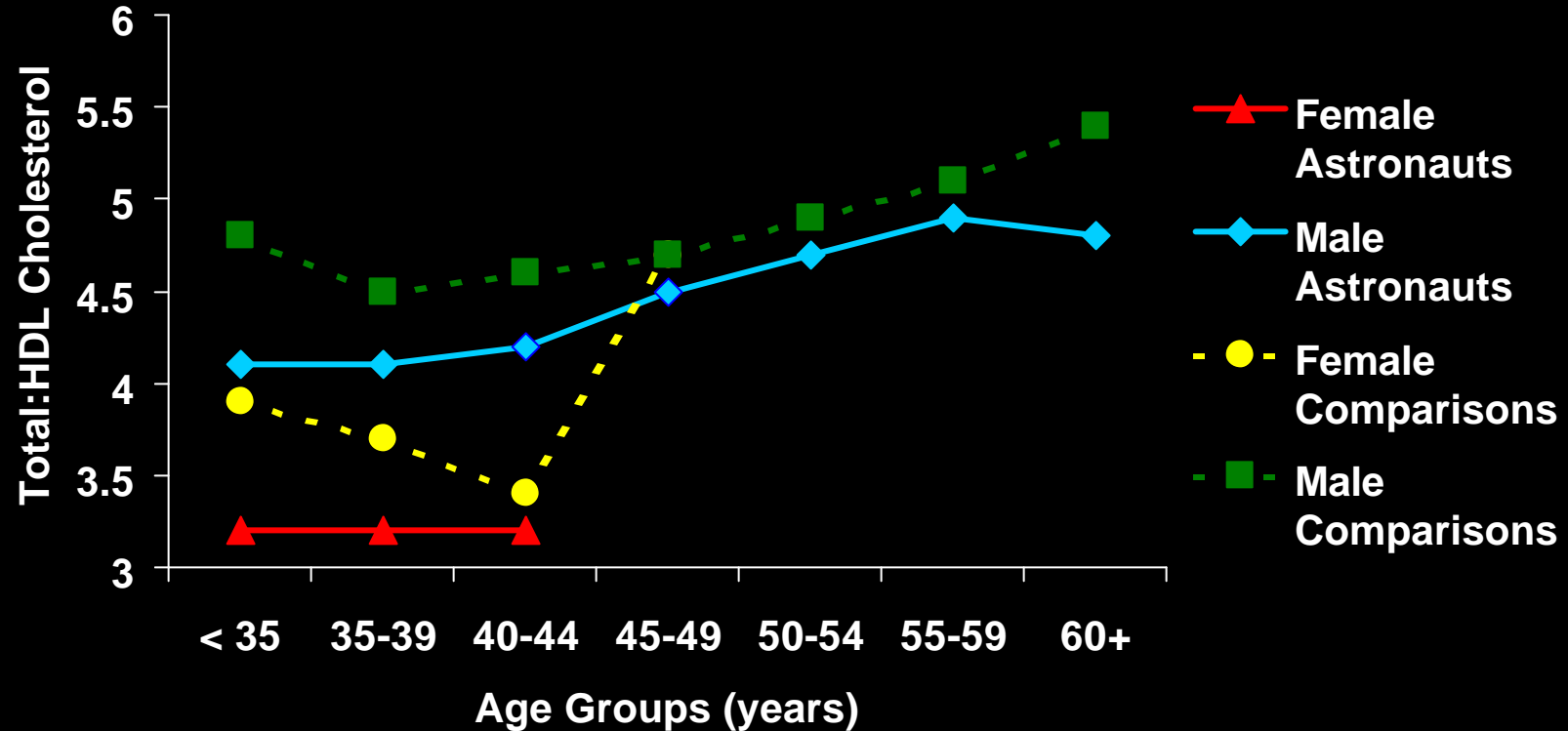
Mean Values by Age (Cross-sectional data, 1991-1998)





Ratio of Total to HDL Cholesterol

Mean Values by Age (Cross-Sectional Data)





Medical Events

Cardio-vascular adaptations

Dry skin, Erythema of face & hands, Excessive wax in ear, Fatigue, Foreign body in eye, Gastrointestinal discomfort, Musculoskeletal

Neuro-vestibular alterations

changes, Nasal congestion/irritation, Psychiatric distress, Sleep disorders, Sleeplessness, Space motion sickness, Superficial injury, Surface burn to

Bone & muscle changes

hands, Glossitis, Headache, Heartburn/ gas, Hematoma, Hemorrhoids, Injury/trauma, Laryngitis, Infection/irritation, Acute

Metabolic/hormonal shifts

respiratory infection, Arrhythmia, Bruise, Conjunctivitis, Contact dermatitis, Contusion of eyeball, Dental caries



Countermeasures

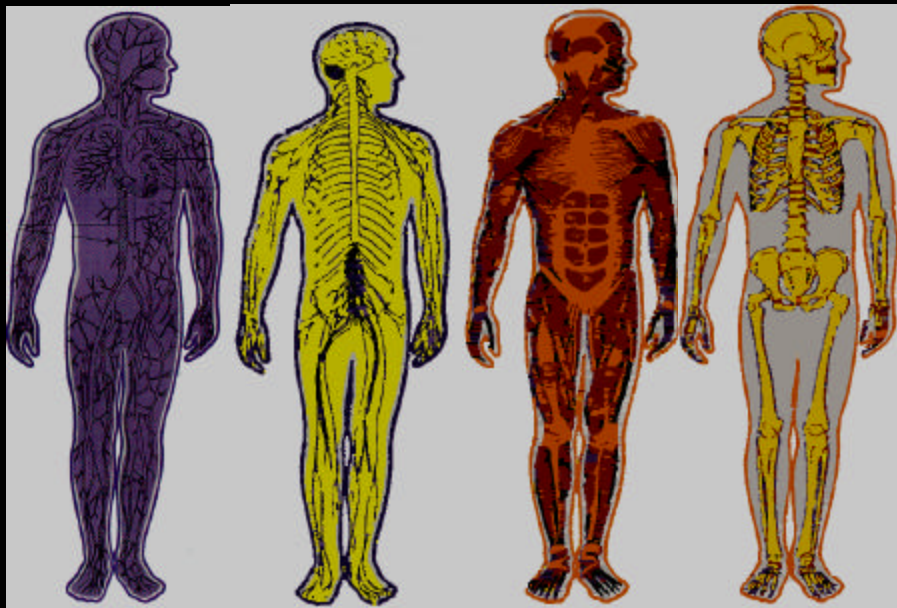
Mechanism

Plasticity

Receptor
adjustment

Long chain
myosin

Bone
formation



Ataxia Fluid loss (2 L),
BP control Muscle fiber
shift & strength
decrease Reduction
1%/ month

Manifestation

♦ **Traditional**

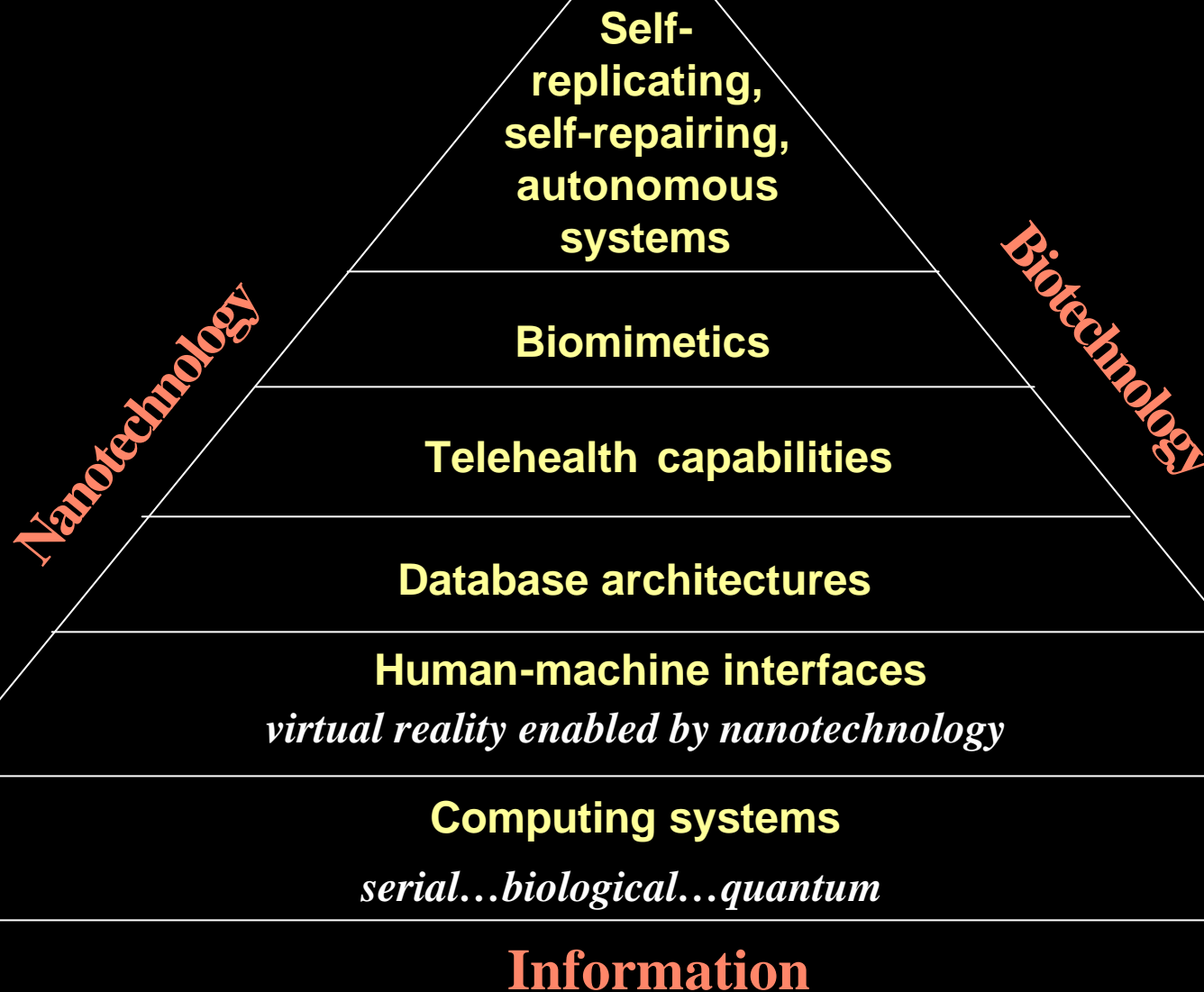
- Exercise
- Nutrition
- Fluids
- Pharmacological supplements

♦ **Non-traditional**

- Artificial gravity
- Intervention at genetic/molecular level



Hierarchy of Medical Technologies

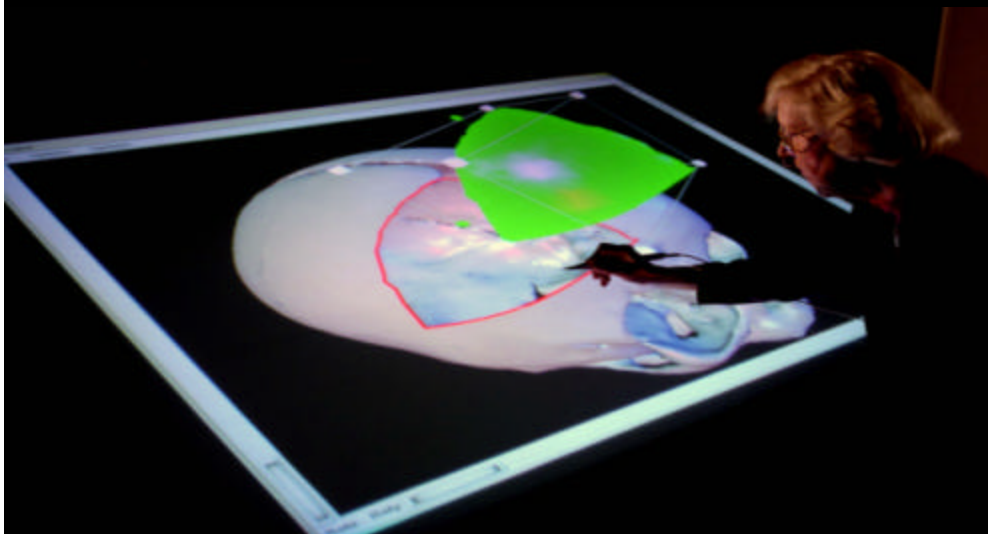




Medical Care Trends

Time and distance = self-sufficiency

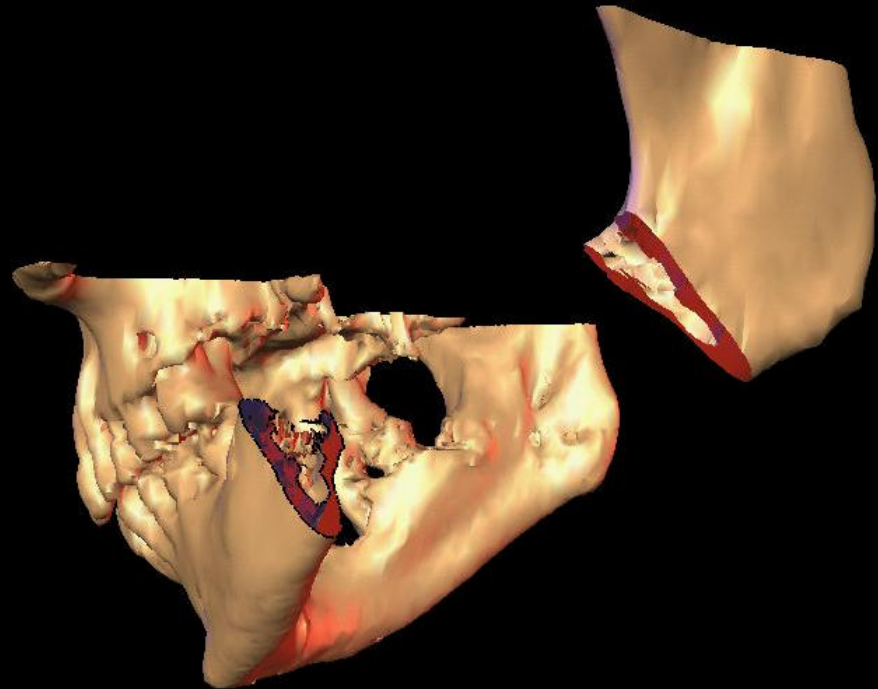
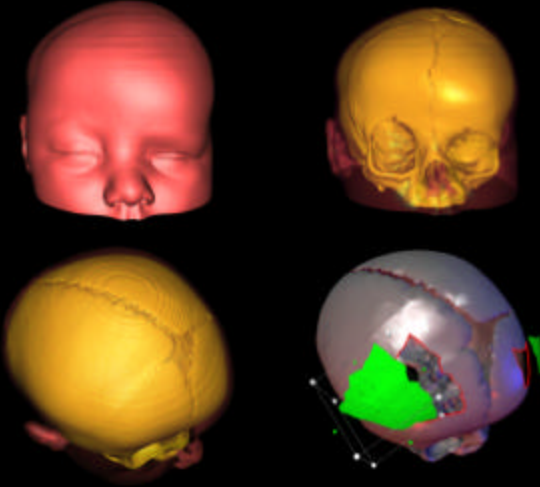
- ◆ Portability
- ◆ Virtual reality
- ◆ Haptic “smart” systems
- ◆ Biologically-inspired technologies





Informatics

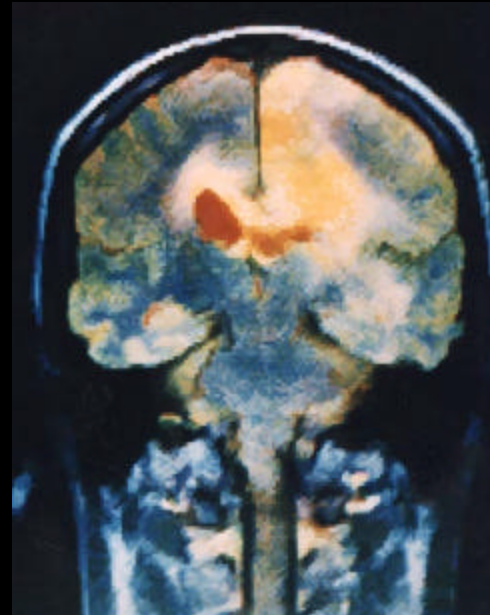
- ◆ **Biocomputation**
- ◆ **Imaging**
- ◆ **Training and simulation**
- ◆ **Telemedicine**





Miniaturization

- ♦ **Imagers**
 - X-ray
 - MRI
 - Ultrasound
- ♦ **Sensors, effectors, and transmitters**
 - Surgical instruments
 - Analyzers





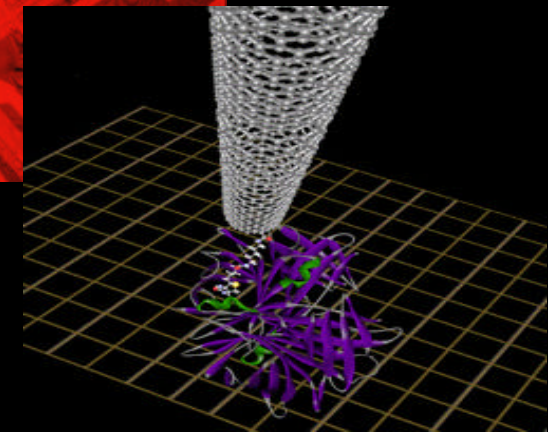
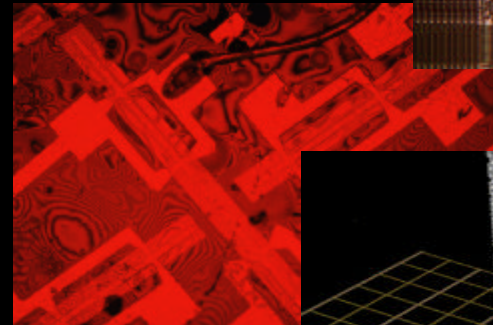
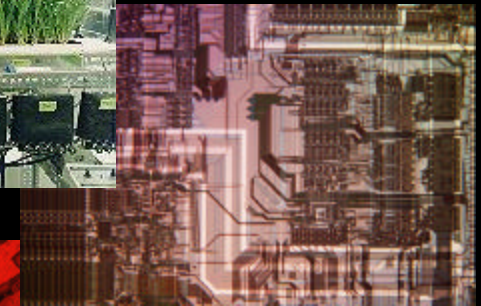
Nanotechnology

♦ Life support

- Sensors and effectors
- Bioregeneration
- “Humans-on-a-chip”
- Biological niches

♦ Medical care

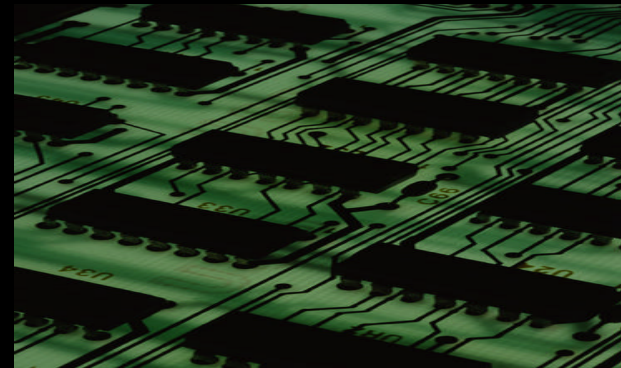
- Diagnostic probes
- Treatment & delivery systems
- “Keyhole” surgery
- Tissue replacement





Human-Machine Interface

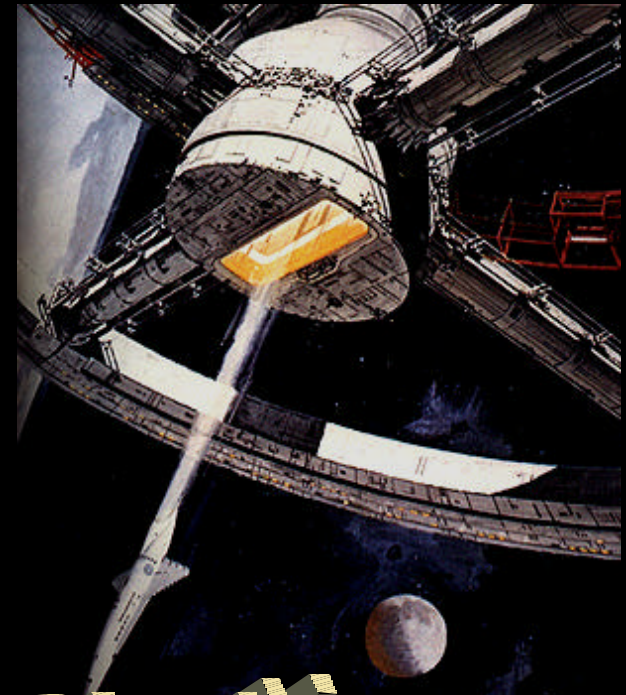
Human-centered systems are an integral part of mission design





Biology / Medicine

- ♦ **Genetic profile of travelers**
 - Tailored medical preparations
 - Individual health maintenance
- ♦ **DNA therapies**
 - Countermeasures
 - *artificial gravity as a medical tool*
 - Illness risk reduction
 - Pre-clinical treatments

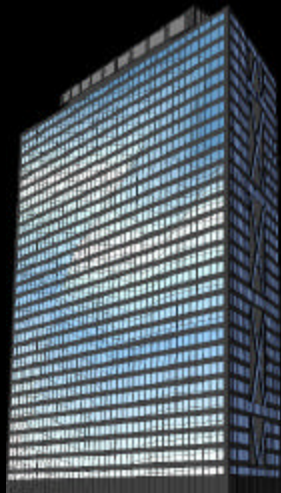
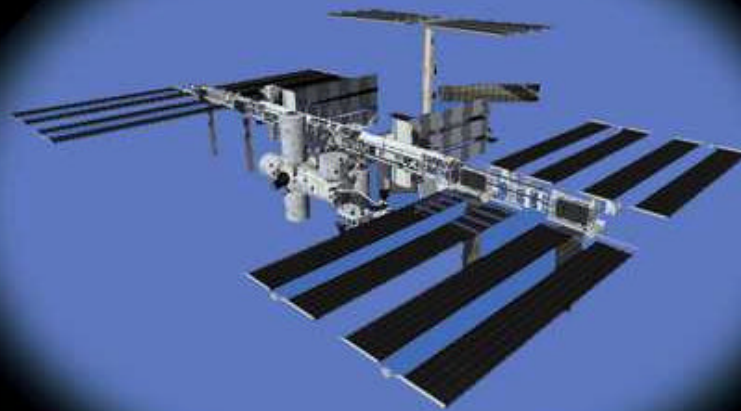


Technology & Bioethics





The Multipurpose ISS

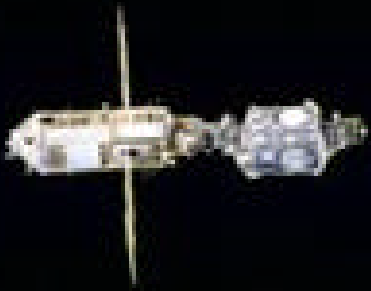




Human Support Technology

Today

- ♦ **Mechanical**
- ♦ **Operator-dependent**



*Technological
Evolution &
Revolution*

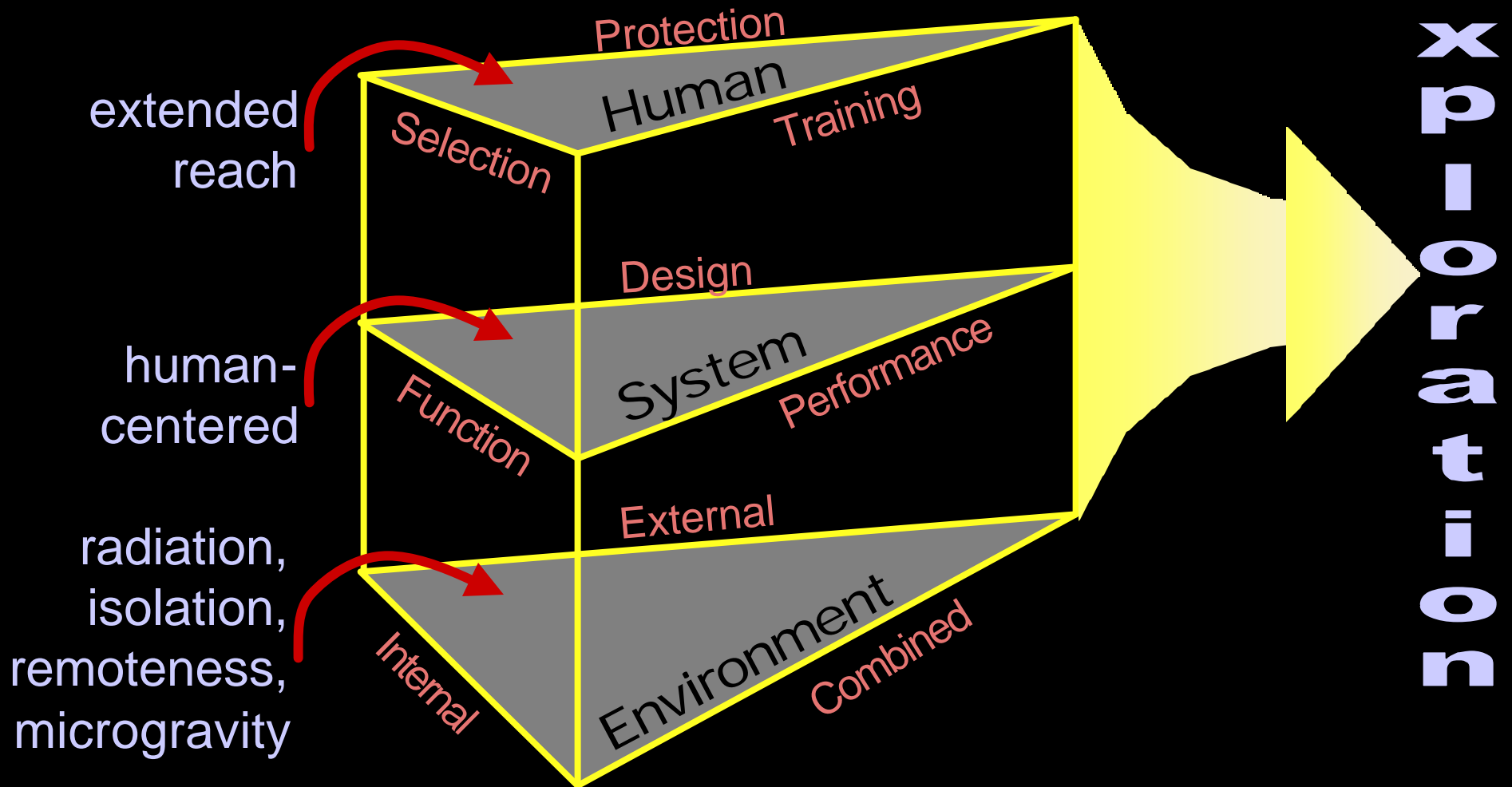
Tomorrow

- ♦ **Adaptive**
- ♦ **Autonomous**
- ♦ **Self-replicating**
- ♦ **Virtual**
- ♦ **Human-centered**





Human Space Missions: The Future





Conclusion

- ◆ Understand the human and the environment
- ◆ Research and understand the Earth-space connection
- ◆ Apply technology to challenging environments on Earth

